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14. ABSTRACT

The PI's and ASU students/staff deployed their coherent Doppler lidar from May 9, 2007 to June 11, 2007 in support of the Canopy Horizontal Array Turbulence Study (CHATS). The experiment took place in a walnut orchard near Davis, California. The overall purpose of the experiment was to investigate the character of within-canopy Sub-Filter-Scale motions. The full experiment occcured in two segments: A) from March 18 – April 18, and B) from May 10 – June 10th. The time period between the two measurement periods corresponded with the transition of the walnut grove from bare branches to full foliage. The ASU lidar group joined the experiment for the second phase. The primary motivations of the ASU lidar deployment were:

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**Report Title**

Coherent Doppler Lidar Deployment in the Canopy Horizontal Array Turbulence Study

**ABSTRACT**

The PI's and ASU students/staff deployed their coherent Doppler lidar from May 9, 2007 to June 11, 2007 in support of the Canopy Horizontal Array Turbulence Study (CHATS). The experiment took place in a walnut orchard near Davis, California. The overall purpose of the experiment was to investigate the character of within-canopy Sub-Filter-Scale motions. The full experiment occured in two segments: A) from March 18 – April 18, and B) from May 10 – June 10th. The time period between the two measurement periods corresponded with the transition of the walnut grove from bare branches to full foliage. The ASU lidar group joined the experiment for the second phase. The primary motivations of the ASU lidar deployment were: 1) to illuminate the connection between the larger-scales and the canopy flows, 2) to gather Doppler lidar data appropriate for 4DVAR analysis, 3) to characterize small-scale winds and turbulence in the canopy flows, and 4) to characterize boundary layer behavior such as the evolution of boundary layer height. Generally, the instrument operated well with only a few down periods during the month. The volume of data collected was typical for a deployment of this length filling 42 data DVD's. Generally, data quality was high and the planned scans for supporting the experiment were executed successfully. For example, a large amount of low-level PPI scans over the array area, and fast volumetric scans in anticipation of 4DVAR analysis were both obtained, as planned. The latter scans were timed to correspond with a helicopter deployment which took place toward the beginning of the second phase of the experiment. Preliminary examples of the visualization of the gathered lidar data are provided below.

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## List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

### (a) Papers published in peer-reviewed journals (N/A for none)

**Number of Papers published in peer-reviewed journals:** 0.00

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### (b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

**Number of Papers published in non peer-reviewed journals:** 0.00

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### (c) Presentations

**Number of Presentations:** 0.00

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### Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

**Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):** 0

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### Peer-Reviewed Conference Proceeding publications (other than abstracts):

**Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):** 0

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**Number of Manuscripts:** 0.00

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**Number of Inventions:**

### Graduate Students

| NAME | PERCENT_SUPPORTED |
|---|---|
| Raghavendra Krishnamurthy | 0.35 |
| Shantanu Kongara | 0.35 |
| Charles Retallack | 0.35 |
| **FTE Equivalent:** | **1.05** |
| **Total Number:** | **3** |

### Names of Post Doctorates

| NAME | PERCENT_SUPPORTED |
|---|---|
| **FTE Equivalent:** | |
| **Total Number:** | |

### Names of Faculty Supported

| NAME | PERCENT_SUPPORTED |
|---|---|
| **FTE Equivalent:** | |
| **Total Number:** | |

### Names of Under Graduate students supported

| NAME | PERCENT_SUPPORTED |
|---|---|
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### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: ...... 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

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### Names of Personnel receiving masters degrees

| NAME |
|---|
| **Total Number:** |

## Names of personnel receiving PHDs

NAME

**Total Number:**

## Names of other research staff

| NAME | PERCENT_SUPPORTED |
|---|---|

**FTE Equivalent:**

**Total Number:**

## Sub Contractors (DD882)

## Inventions (DD882)

## 1. Objectives and Motivations

The general objectives for the field experiment, Canopy Horizontal Array Turbulence Study (CHATS, Lenschow *et al.* 2006), were to investigate the character of within-canopy Sub-Filter-Scale (SFS) motions, where "SFS" refers to motions in the atmosphere below the resolution of the numerical grid (or filter) in Large-Eddy Simulations (LES). CHATS was an extension of previous deployments involving horizontal arrays of sonic anemometers/thermometers, see for example, Horst *et al.* 2004. Large-Eddy Simulation has been making significant progress toward understanding the canopy flows and their connections with planetary boundary layers (Patton *et al.* 2003). However, because LES requires *semi-empirical* sub-filter-scale models to account for motions below the size of the numerical filter, they should be validated for different kinds of scenarios, and, in particular, for canopy flows. The full experiment occurred in two segments: A) from March 18 – April 18, and B) from May 10 – June 10th. The time period between the two measurement periods corresponded with the transition of the walnut grove from bare branches to full foliage. The ASU lidar group joined the experiment for the second phase.

The primary motivations of the ASU lidar deployment were: 1) to illuminate the connection between the larger-scales and the canopy flows, 2) to gather Doppler lidar data appropriate for 4DVAR analysis, 3) to characterize small-scale winds and turbulence above the canopy, and 4) to measure properties of boundary layer development, such as, the evolution of ABL height and aerosol levels.

## 2. Lidar Setup and Field Setting

The PI's and students/staff deployed the ASU coherent Doppler lidar from May 9, 2007 to June 11, 2007 in support of CHATS. The central NCAR array was located in a walnut orchard near Davis, California, and the ASU lidar was located 2.05 kilometers to the east with a clear line of sight of the orchard, see Figure 1. With an azimuthal angle 279 degrees and an elevation angle of 0.75 degrees, the ASU lidar pointed at the top of the 30 m tower. In Figure 1, an example radial velocity field obtained from the lidar is superimposed on a satellite photo of the fields north of the small city of Dixon, California. Dixon is approximately six miles west of Davis, California, on Highway 80 (which can be seen to the south of the lidar scanning area). Compare the heterogeneity of crop types and field sizes to the lidar domain size.

The view from the lidar toward the west and the walnut orchard can be seen in Figure 2. The ASU lidar was located near the NCAR sodar/RASS deployment site, as can be seen in Figure 3 (photo taken looking east from the NCAR sodar/RASS). Views to the northwest and to the southwest are shown in Figures 4 and 5, respectively. These figures demonstrate the relatively smooth agricultural fetches surrounding the orchard, with the exception of a collection of 1-2 story buildings in Dixon which were upwind of the orchard only if winds originated from the south to southeast.

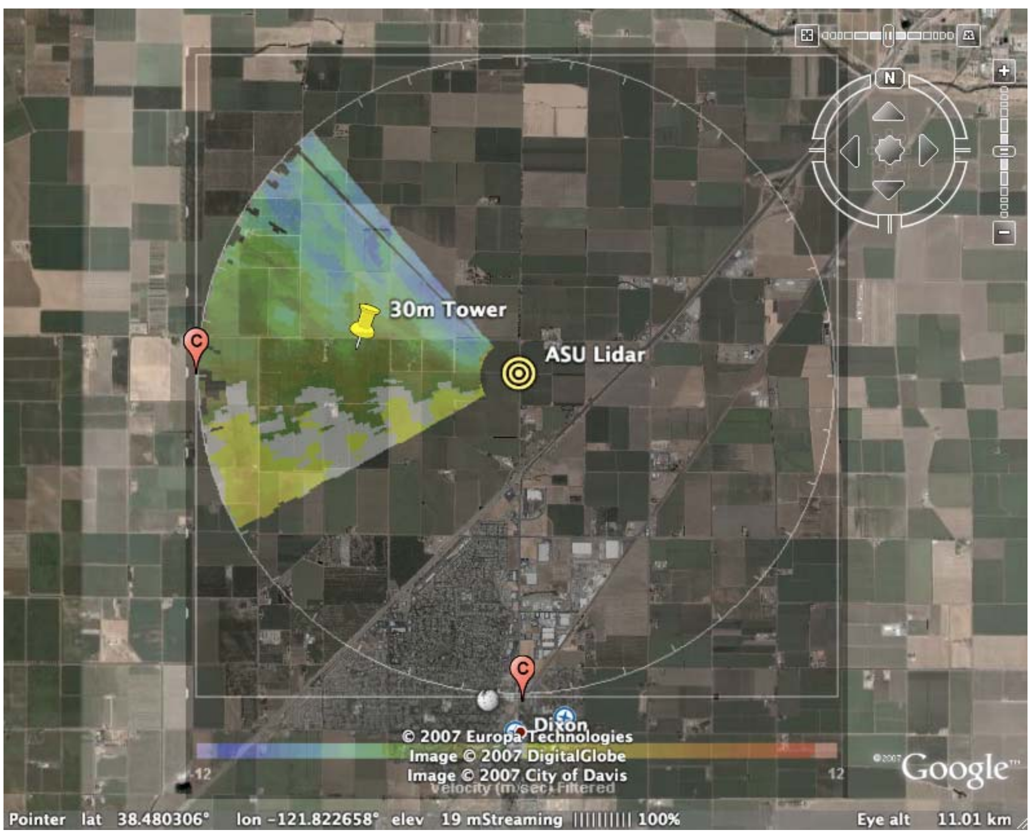


Figure 1. Superimposed lidar radial velocity field on satellite image. Note location of ASU lidar and main tower are given. Note the field heterogeneity relative to the lidar scanning domain. Radius of displayed scanning range is 4 km.

Figure 2. View towards the central CHATS tower from ASU lidar (looking toward the west). Note NCAR sodar/RASS can be seen in the foreground to the right.

Figure 3.  View towards ASU lidar (looking east) near NCAR sodar/RASS, seen in the foreground.

Figure 4.  View towards the northwest from ASU lidar.

Figure 5.  View towards the southwest from ASU lidar.

*2.1 Preparatory Tasks*

A series of preparatory tasks was completed before the experiment began in May. The main tasks were:

A) Laser transceiver was shipped to Colorado and tuned; also *analog front end* underwent checking and basic maintenance.

B) PI's conducted a lidar siting trip to CHATS location. An agreement with local farm owners was arranged for renting the deployment site.

C) An electrical power agreement was arranged (a power drop from power line).

D) Installation of the power drop by a local electrician.

E) Lidar preparation, dismantling, and packing took place April 25-May 1$^{st}$.

F) Equipment transport to CHATS site -- May 2 – May 5$^{th}$.

G) Lidar assembly and testing May 8$^{th}$ – May 11$^{th}$.

H) Lidar alignment and geospatial reckoning of key landmarks, towers, etc.

*2.2 Data Acquisition*

Data acquisition and archival of data took place between May 12$^{th}$ to June 10$^{th}$. Noteworthy events which occurred during the data acquisition are given below:

1) A power failure took place on May 13, due to local farmer shutting down main breaker at power pole.
2) By May 14$^{th}$, hardware was back online in time for successful data acquisition during period of helicopter sampling by R. Avissar's group.
3) On May 15$^{th}$, three small fires in fields within scanning domain are noticed.
4) On May 15$^{th}$, 4DVAR fast volumetric scans took place.
5) On May 22$^{nd}$, stare scan over canopy. Fuse on electronic rack burned out, recording stopped, fuse replaced, scanning resumed. PPI stack for dissipation calculations initiated. Dr. Ned Patton requested specific scanning pattern (mixed PPI and RHI) which was initiated by 14:43 this day.

6) On May 24th, plowing on fields NW and SW of lidar, dust clouds present. Re-initiated stare scan just south of 30 m tower @ 14 m level. Alternated between stare at .308 degree elevation and 5 degree elevation.
7) June 1, initiated “gust capture” low level PPI scans.
8) On June 3, hot air balloons within domain, effects seen as beams impact balloons.
9) June 4, “gust capture” scans still running, plowing of field due east of lidar deployment site.
10) June 6, haying of fields SW of lidar, balloons north of lidar, winds still, no clouds.

### *2.3 Deployment breakdown, Lidar state-of-repair*

Lidar breakdown and shipping back to ASU took place from June 12 – June 15. The lidar remained in good working condition with the exception of a field alteration of the air flow within the shelter to enhance cooling directly on the transceiver. We found this fix necessary to maintain stability of the laser signal during the latter part of this deployment.

## 3. Data and Quality

Generally, the instrument operated well with only limited down periods during the month. The volume of data collected was typical for a deployment of this length filling 42 data DVD's. Data was archived in typical *.PRD format for this type of lidar. Generally, data quality was high and the planned scans for supporting the experiment were executed successfully. Acceptable quality was typically obtained for the lidar signal to a range of approximately 4 kilometers, though this varied significantly depending on daily aerosol and humidity levels. Examples of scanning methods were: mixed PPI/RHI’s, low-level PPI’s for gust tracking, and fast volumetric scans in anticipation of 4DVAR analysis. Some of the latter scans were timed to correspond with a helicopter deployment which took place toward the beginning of the second phase of the experiment.

## 4. Preliminary Sample of Data Processing

Preliminary examples of the processing of the gathered lidar data are provided below. In Figure 6, radial velocity on a 1.3 degree elevation PPI at 10:02 a.m. on June 7, 2007, is displayed. Winds are from the north with a slight westerly component. The laser return signal was strong out to 4 km range, providing sufficient coverage for the goals of the coherent Doppler deployment. Winds were relatively strong from approximately -10 m/s (towards the lidar) to 10 m/s (away from the lidar) with some streaky structure and gusts visible.

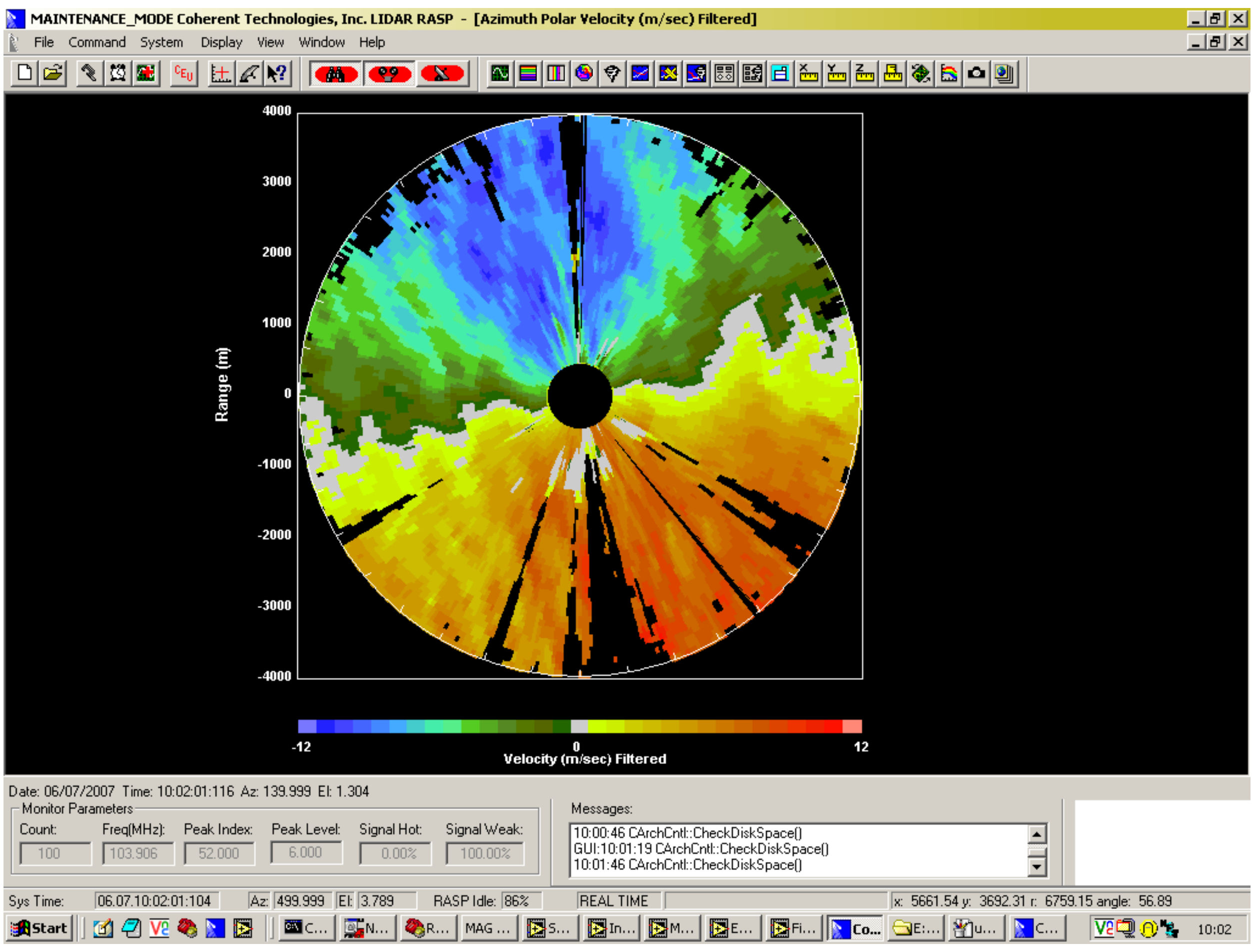


Figure 6. Radial velocity on 1.3 degree elevation PPI at 10:02 a.m. on June 7, 2007 during CHATS. Blue represents flow toward lidar; orange/red – away.

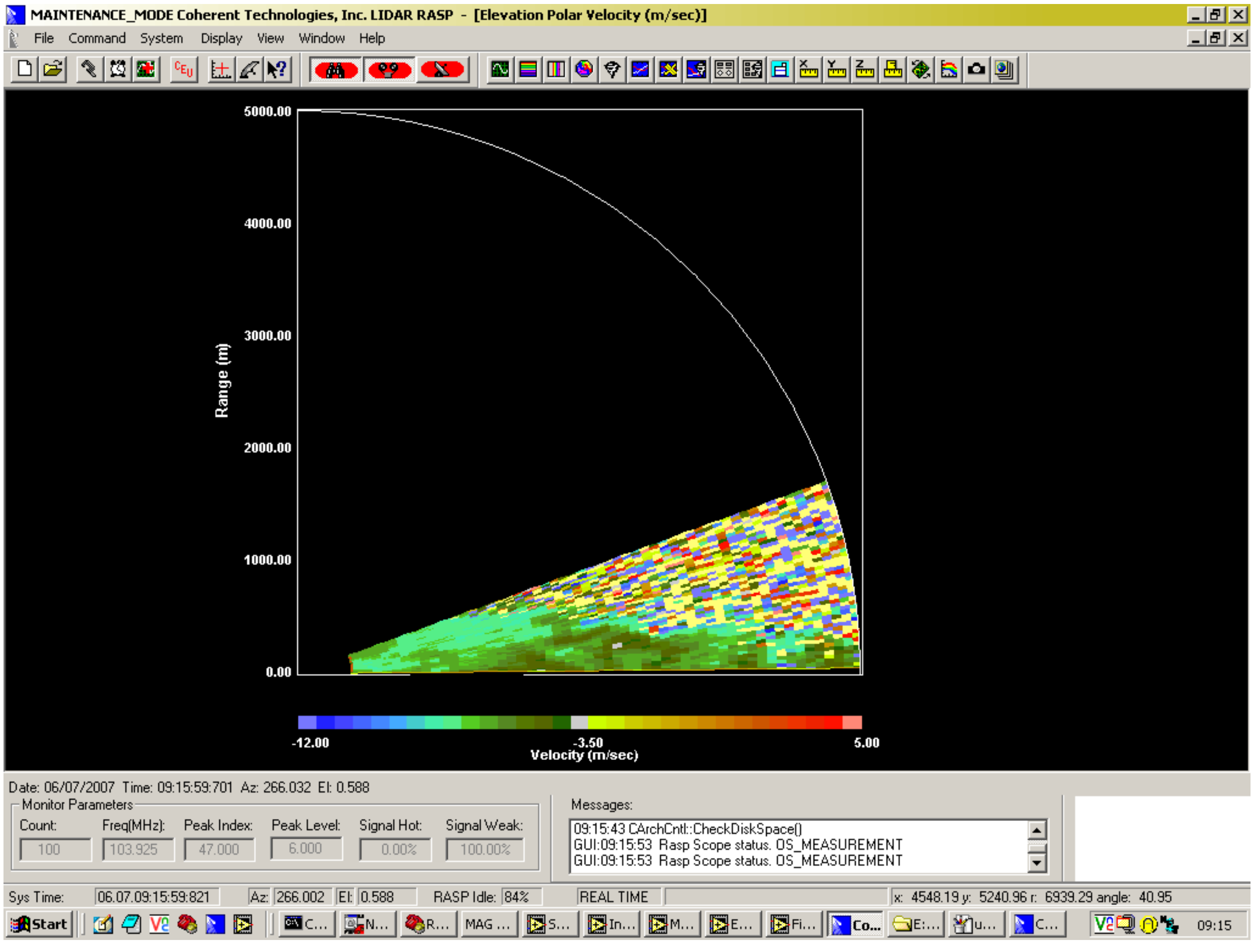


Figure 7. Radial velocity on an RHI at 266 degrees azimuth (clockwise from north) at 9:16 a.m. on June 7, 2007 during CHATS.

In Figure 7, one can see the approximate height of the boundary layer over the horizontal array range (~2 km) reaches roughly 700 m at 9:16 a.m. Winds are moving toward the lidar with higher velocities at approximately 7 m/s. There appears to be a thickening of the boundary layer over the orchard, possibly associated with increased roughness.

## 5. State of the Data and Planned Analysis

The data is currently maintained at ASU on a series of 42 DVD's and on two hard drives and is available upon request. Basic matlab scripts for the processing of the data will also be provided upon request. A proposal is currently being written to request support for in-depth data analysis of the acquired coherent Doppler lidar data.

## 6. Summary

The ASU coherent Doppler lidar has been deployed according to plan in support of the CHATS experiment. While some hardware issues arose, necessitating field fixes (e.g., adaptation of the air flow system), in general, the data was good and the quantity gathered was typical for a month deployment of this type. Therefore, the quality and quantity of the data gathered is appropriate for further in-depth analysis – in satisfaction of the major goals of this project at this stage.

## 7. Journal, Conference Papers, and Theses

None, at this time.

## 8. Acknowledgements

The support of the Army Research Office and the guidance of Program Manager Dr. Walter Bach are gratefully acknowledged (*contract/grant number W911NF0710137)*. Also, frequent discussions with the NCAR team and their willingness to allow lidar deployment in the vicinity of their sodar/RASS were greatly appreciated.

## 9. References

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